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Method and device for producing a three-dimensional object

The invention relates to a method and a device for producing a three-dimensional object according to the preamble of patent claims 1 to 9.

A device for producing a three-dimensional object by means of stereolithography is known.

The structural resolution in objects produced by stereolithography is limited, however. In the process of micro-photo solidification instead of a laser beam an expanded light source is used and selective solidification of the layer takes place corresponding to the cross-section via a digitally controllable mask in the form of a transmission liquid crystal plate. The process of micro-photo solidification enables a higher structural resolution by means of a reducing projection of the exposure mask on to the polymer surface. In the process of micro-photo solidification higher demands, conditional on the higher possible structural resolution, are made on the accuracy of the exposure. In particular areas of a layer not connected to previously compacted layers, because, for example, they bridge a hollow space or form an overhang, make high demands on the accuracy of the exposure.

It is the object of the invention to provide an improved device for producing a three-dimensional object by using a mask, with which objects with higher structural resolution can be produced.

The object is achieved by a method or a device according to patent claim 1 or 9. Further developments of the invention are cited in the subordinate claims.

Further features and advantages of the invention emerge from the description of an embodiment example using the figures.

Fig. 1 shows a schematic cross-sectional view of the device.

Fig. 2 shows a schematic illustration of an object to be formed.

As can be seen from Fig. 1, the device has a container 1, open on its upper side, with an upper edge 2. In the container a carrier 3 for carrying an object 4 to be formed is arranged, with a substantially flat and horizontally aligned construction platform 5, which can be displaced forwards and backwards and positioned in the container 1 by means of a schematically indicated height adjustment device 6. The platform 5 has a circular cross-section. The entire container 1 is filled to a level or a surface below the upper edge 2 with a liquid plastics material 7 which can be hardened by light.

At a predetermined distance below the upper edge 2 of the container 1 is provided a flat, transparent plate 11 made of a material transparent to visible light, for example of white glass, which is mounted on the device via a holder 12 in such a way that when the container is filled with the material it dips into the material by a predetermined amount. The holder 12 is displaceable above the container 1 via a drive and can be positioned at a desired position above the construction

platform 5. The transparent plate 11 is further adjustable in inclination and height via an adjustment device, so it [can be] aligned perpendicular to the optical axis of a later described exposure device and parallel to the construction platform. On its lower side facing the upper side of the construction platform 5 the transparent plate 11 is coated with a material to which the plastics material 7 does not adhere when it has been solidified by the action of electromagnetic radiation.

Above the container 1 an exposure device 20 in the form of an LCD projector (liquid crystal display projector) known per se is provided. The exposure device 20 has a light source 21 for generating visible light, for example in the form of a halogen lamp, as well as a mask-generating device arranged between the light source 21 and the container 1 in the form of a liquid crystal (LC) display or a liquid crystal plate. Between the light source 21 and the LC display 22 is provided a projection optic, not illustrated, for homogeneous irradiation of the LC display. The LC display 22 is constructed as a transmission LC display with high resolution, for example 800x600 pixels and 256 gray scales, which can be triggered as a function of data defining the cross-section of the object to be formed in the respective layer. The LC display therefore forms a mask for exposure in the respective layer. The LC display is further constructed in such a way that each pixel can be triggered in such a way that it possesses a desired transparency of between 0 and 100% of the impinging light power, in that the individual gray scales are triggered.

The exposure device also has an optic 23, arranged between the LC display 22 and the container 1, in the form of a zoom lens

for reduced or enlarged imaging of the mask generated by the LC display on to the transparent plate 11. Preferably the optic 23 is constructed as a reducing optic with adjustable reduction, which, by reduced imaging of the mask, enables a higher structural resolution to be obtained. The arrangement of the exposure device 22 and the transparent plate 11 relative to one another is such that the focal plane of the optic 23 coincides with the lower side of the transparent plate 11, so a sharp image is generated there.

As can be seen from Fig. 1, in the beam path between the exposure device 20 and the container 1 a shading device in the form of a diaphragm 25 is provided to stop down the light. The diaphragm 25 can be pivoted into the beam path and out again via a schematically indicated pivoting device.

A semi-transparent mirror 26 is further arranged in the beam path at 45% to the optical axis, whereby a portion of the light beams of the image beam path is masked. Further provided is a detector 27 with which the light masked via the semi-transparent mirror 26 is captured. As the masked light is an image of the mask a flat detector is required. For example the detector 27 is constructed as a CCD camera.

The entire exposure device 20 is displaceable in the vertical direction via a drive, so the distance between the LC display and the transparent plate for setting a field to be exposed is adjustable.

Further provided is a control device 30 with a computer, which is constructed in such a way that it controls the mask-generating device 22 in the exposure device 20 and the height

adjustment device 6 and the diaphragm 25 centrally and as a function of a construction program dependant on the object data. The control device 30 is constructed in such a way that it triggers the mask-generating device 22 as a function of the data which in each case characterise the cross-section of the object to be formed. The control device 30 is further constructed in such a way that the construction platform 5 can be lowered step by step relative to the lower side of the transparent plate 11 by the amount corresponding to the thickness of a layer and the diaphragm 25 is pivoted into the beam path if no exposure of the surface of the plastics material is to take place or the diaphragm 25 is pivoted out of the beam path before exposure of a layer begins.

In the method according to the invention first layer data for the cross-section of the object in each layer are generated from predetermined object data, for example CAD data, in the known way. Then in a first step the container 1 is filled with the liquid plastics material 7. As plastics material a polymer is used which hardens under the action of visible light. The transparent plate 11 is adjusted in such a way that it is arranged horizontally at a predetermined place above the construction platform 5 and parallel to it, as well as perpendicularly to the optical axis of the exposure device. In a second step the carrier 6 is displaced via the height adjustment device in such a way that the surface of the construction platform 5 is located below the lower side of the transparent plate 11 by an amount corresponding to the desired thickness of the layer. In this way a layer of the liquid plastics material, which can be hardened by light, is located between the upper side of the construction platform 5 and the lower side of the transparent plate 11.

Then exposure of the first layer takes place. The LC display 22 is triggered via the control device 30 corresponding to the layer data corresponding to the first layer of the object to be solidified, so the LC display forms a mask which lets through the light transmitted by the light source 2 at the places corresponding to the cross-section of the object in this layer and at the remaining places is non-transparent. Because of the image of the mask projected by means of the optic 23 on to the transparent plate 11 exposure of the layer of the liquid plastics material located below the transparent plate 11 takes place only at those places corresponding to the image.

The construction program for the object to be formed, in addition to the layer data of the cross-section of the object to be formed as a function of the object data in each layer, generates information, in which, as can be seen in Fig. 2, is cited which areas 50, 50′ of the layer to be formed are to be connected to compacted areas located below and which areas 51, 51′ are to be formed via non-solidified areas of a layer located below. Fig. 2 is a schematic illustration of an object 4 under construction, in which in the top solidified layer 4′ the area 51 bridges a hollow space located below, which during construction contains non-solidified material and in which the area 51′ represents the beginning of an overhanging or projecting part of the object to be formed. By means of this additional information in the layer data the LC display 22 is triggered via the control device 30 in such a way that areas 50, 50′, which are exposed via already solidified areas with a light intensity 10, sufficient to penetrate this area of the layer and to connect it to the area located below. The areas

51, 51′ are exposed with a light intensity 11, which is reduced in comparison to 10 by up to 50%, set via the gray scales of the LC display. This guarantees that the area 51, 51′ to be solidified is hardened only to the depth of one layer thickness. Any other light intensities can also easily be set via gray scale exposure.

The intensity profile of a layer is ascertained via the detector 27 and used to control the exposure of the following layer or following objects. Using the measured intensity profile the intensity profile actually impinging on the layer can be calculated and then either the exposure time or the light intensity can be controlled via the LCD (gray scales) and/or the light source. Calculating the light intensity via the mirror and the detector also serves to compensate an occurring drop in lamp power, which sometimes occurs after as little as 10% to 20% of the maximum working life of a lamp.

After the exposure of a layer the diaphragm 25 is pivoted into the beam path to prevent light falling on the plastics material in the container during setting of the next layer and this being solidified at undesired places. Then the construction platform 5 is lowered by an amount corresponding to the thickness of a layer. During lowering of the construction platform 5 there arises between the transparent plate 11, arranged as fixed, and the last exposed and therefore hardened layer a negative pressure which ensures that plastics material subsequently flows into the thus generated intermediate space between the transparent plate 11 and the last solidified layer. After the new layer has been set the above-described steps are repeated until the object is complete.

By setting the light intensity via the gray scale exposure and the high resolution of the LC display it is possible to obtain the highest structural resolutions, in particular with objects with outer dimensions in the millimetre range or below.

In an alternative embodiment a digitally triggered mirror system (digital mirror display) or a laser projection display or a laser mask are used as mask-generating device, rather than an LC display.

In a further embodiment of the method according to the invention intensity control of the exposure light via control of the mask is used to harden successive layers with the same cross-section at the same time, by raising the light intensity.

In general, control of the light intensity and therefore the energy input into the material to be compacted via the digital control, i.e. by pixels, of the transparency of the mask allows control both of the depth of compaction within a layer and also over many layers.